for producing landmark heat maps and occlusion heat maps. For example, network module **204** may be trained using training images labelled with selected landmark points (e.g., corners of eyes, tip of nose, corners of mouth, etc.) and occlusion indicia (e.g., different amounts and locations of occlusion) to generate operating parameters for the network circuitry. In some embodiments, network module **204** is trained with training data where landmark points are occluded and the data is labelled with where the landmark points are estimated to be located (e.g., a network trainer may indicate (click) where the landmark points are thought to be located).

[0043] Network module **204** may generate landmark heat maps **206** and occlusion heat map **208** as high-level grid representations of image input **202**. For example, network module **204** may generate landmark heat maps **206** and occlusion heat map **208** as n×n grid representations of image input **202** where n×n is a lower resolution (e.g., lower number of pixels) than the image input. Thus, each heat map may be an n×n grid of regions or cells representing input image **202**. In one embodiment, landmark heat maps **206** and occlusion heat map **208** are 16×16 grid representations of image input **202**, which is a 128×128 pixel image.

[0044] Landmark heat maps **206** generated by network module **204** may include one heat map for each selected landmark point of interest in image input **202**. The selected landmark points of interest may be predetermined for network module **204**. For example, in one embodiment, landmark heat maps **206** includes 7 heat maps—1 heat map for each corner of each eye, 1 heat map for the tip of nose, and 1 heat map for each corner of the mouth. While the corners of the eyes and mouth and the tip of the nose are described as landmark points herein, it is to be understood that any landmark points may be used and any number of landmark points for a landmark may be used. For example, the nose may be defined by additional landmark points such as the sides of the nose in addition to the tip of the nose. As another example, cheek bones may be selected as a landmark and represented by landmark points for each cheek.

[0045] Landmark heat maps **206** may be grid representations of image input **202** with each region (e.g., cell) having a value (e.g., a vector or number) that represents the likelihood that the landmark point is in that region. For example, the value in each region may be a number between 0 and 1 with 0 being not likely to be the landmark point and 1 being substantially likely to be the landmark point. Landmark heat maps **206** may be displayed as grayscale images with grayscale intensity representing the different values in each region. FIG. **6** depicts a representation of an embodiment of a grayscale image for an example of landmark heat map **206**A. The features of face **300** are shown, for reference, as dashed lines in FIG. **6**. The features of face **300**, however, may not be visible in landmark heat map **206**A.

[0046] Landmark heat map **206**A is a representation of a heat map for landmark point **302**. As shown in FIG. **6**, landmark point **302** (the diamond) is the landmark point for the corner of the mouth on face **300**. Landmark heat map **206**A includes a 16×16 grid of regions **304** with each region having a grayscale value (e.g., grayscale intensity) representing the likelihood that landmark point **302** is in that region. Regions **304** around landmark point **302** are whiter than other regions further away from the landmark point because the likelihood that the landmark point **302** is in one of these regions is higher than the landmark point being in other regions. For example, as shown in FIG. **6**, the regions (e.g., regions **304'**) around landmark point **302** are different shades of gray (e.g., a grayscale gradient) and are lighter (e.g., more white) as the probability that the landmark point **302** is included in the region increases. Similar landmark heat maps **206** may be generated for each of the other selected landmark points.

[0047] Occlusion heat map **208** may be a grid representation of image input **202** with each region (e.g., cell) having a value (e.g., a vector or number) that measures an amount of occlusion in that region as determined by network module **204**. Occlusion heat map **208** may be displayed as a grayscale image with grayscale intensity representing different values of occlusion in the regions in the image. FIG. **7** depicts a representation of an embodiment of a grayscale image for an example of occlusion heat map **208**. The features of face **300** are shown, for reference, as dashed lines in FIG. **7**. The features of face **300**, however, may not be visible in occlusion heat map **208**.

[0048] Occlusion heat map **208** includes a 16×16 grid of regions **304** with each region having a grayscale value (e.g., grayscale intensity) representing a relative amount of occlusion determined for that region (e.g., a scaled value of occlusion determined for that region). In the example of FIG. **7**, regions **304** around the corner of the mouth are shown as having some occlusion by the higher intensity (closer to white color) of those regions. The occlusion shown in FIG. **7** may be, for example, from the user's hand or a mask covering a portion of the mouth and the corner of the mouth.

[0049] In certain embodiments, after landmark heat maps **206** are generated, landmark locations are identified (e.g., estimated) in identify landmark locations **210**. Identify landmark locations **210** may include generating two-dimensional representations of where the selected landmark points (e.g., landmark point **302**) are positioned in each landmark heat map **206**. The two-dimensional representation may be, for example, a two-dimensional vector representation of x- and y-coordinates of the landmark point with respect to the grid representing the heat maps.

[0050] In certain embodiments, the x- and y-coordinates for each landmark point are generated by finding the center of gravity in landmark heat maps **206**. For example, as shown in FIG. **6**, center of gravity **306** may be found as the center of gravity of the white (e.g., brightest) area (the "hot" area) in the grayscale image. Center of gravity **306** may be an approximation or estimate of the location of landmark point **302** based on the intensities and distribution of likelihood values for the landmark point. In some embodiments, the intensities and spreads of the likelihood values may be used to assess a confidence value for center of gravity **306** being landmark point **302**.

[0051] The center of gravity for the different landmark points may be found in each of landmark heat maps **206**. Thus, for an embodiment with 7 landmark heat maps **206**, a list of 7 x- and y-coordinates, each coordinate representing one landmark point, may be generated. In some embodiments, the x- and y-coordinates may be represented as a floating-point vector (e.g., a normalized floating point vector).

[0052] In some embodiments, the landmark point in a landmark heat map may be occluded (not visible) and thus the heat map may not provide sufficient information to estimate the location of the landmark point. In such embodi-